Actinide Chemistry

Actinide chemistry serves a critical role in addressing global threats

Project Description

At Los Alamos, scientists are using actinide analytical chemistry to identify and quantify the chemical and isotopic composition of materials. Since the Manhattan Project, such work has supported the Laboratory's mission. Today, actinide analytical chemistry plays a critical role in ensuring the national security of the United States through nuclear science and technology.

The scope of actinide chemistry includes chemical and radiochemical analysis of materials in which actinide elements make up a significant portion of the sample. Analyses range from assay of the major and minor components down to trace analysis of impurities—such work spans more than seven orders of magnitude of chemical analysis capability.

Actinide chemistry underpins the majority of the Laboratory's chemical sciences strengths and serves as a critical component of the plutonium science and research strategy at Los Alamos. Specialized radiological facilities and capabilities for transuranic chemical research at Los Alamos play a vital role in the Department of Energy's weapon complex modernization effort, which slates Los Alamos to be the Center of Excellence for Plutonium Science.

Capabilities

Determining actinide behavior in natural and anthropogenic systems.

- Ascertaining oxidation state and speciation of actinides in natural systems.
- Determining thermodynamics and coordination chemistry in aqueous systems, such as waste tanks and processing operations.
- Developing legacy-waste remediation strategies, including the prediction of radioisotope mobility and speciation in the vicinity of contaminated sites.
- Modeling actinide transport in subsurface environments.

Enhancing the nuclear fuel cycle.

Developing new separation processes to recycle waste.

Better understanding actinides in waste forms.

Conducting molecular characterization and identifying new forensics signatures.

Performing actinide molecular synthesis and characterizations extended to the heavier actinides. Such work includes the study of trends in periodicity.

Research and Technology Development Areas

- For the first time ever, scientists used light energy to create a rare molecular uranium nitride (U-N) complex containing a discrete terminal U-N unit, where the nitrogen atom is bonded only to the one uranium atom, versus prior work in which the nitrogen atom has always been bonded to two or more uranium atoms. Los Alamos scientists used photolysis on a uranium azide—a molecule containing one uranium atom and three nitrogen atoms—exposing it to ultraviolet light and using the energy from a photon to break off nitrogen gas, resulting in a molecule with a single uranium nitride group. This breakthrough is important because uranium nitride materials show promise as advanced nuclear fuels due to their high density, high stability, and high thermal conductivity–enabling them to run cooler in advanced reactors.
- Successfully disassembled nuclear weapons “pits” and converted them into more than 240 kilograms of plutonium oxide, an initial step in permanent plutonium disposition. *Read:* LANL disassembles "pits," makes mixed-oxide fuel.
- Developed the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). The generator keeps the rover’s batter charged night and day, giving Curiosity the potential of being the longest-operating, farthest-traveling, most-productive Mars surface mission in history. *Read:* Los Alamos National Laboratory top science news of 2012.
- Developed a new method designed to produce two new uranium iodide reagents. This cost-effective, environmentally green, and safe method will not only provide a nondestructive path forward for more than 5,300 metric tons of stockpiled nuclear waste but also stands to revolutionize the use of depleted uranium in chemistry, catalysis, materials science, and energy. This breakthrough technology received an R&D 100 Award in 2012.
- Developed a new thorium chloride reagent that one day could enable the development of a nuclear reactor so safe it would never melt down. This new approach not only enables the use of stockpiled nuclear waste as fuel but also will help establish thorium-based reactors as a key sustainable energy source for the future. This breakthrough technology received an R&D 100 Award in 2011.
- Restarted the Isotope Fuels Impact Tester (IFIT). IFIT provides a method to impact plutonium-238 heat sources and subassemblies of radioisotope heat generators to determine the impact response and the effect of different target materials. IFIT has been used to qualify the impact properties of a new generation of radioisotope power systems that will be used for space missions.
- Developing ways to determine the sources of a range of different nuclear materials, such as weapons-grade uranium and plutonium, reactor fuel, and radioactive waste. Such nuclear forensics enable scientists to identify illicit sources of nuclear materials and enable the shutdown of illegal pathways. Capabilities include (1) nondestructive and destructive analyses of both bulk and particle samples for the isotopic compositions of actinides (and thus determine age, origin, and processing history), ultra-trace-level analysis for national security, and high sample range for material interdiction needs. Los Alamos has in place forensic facilities and provides support for the Nuclear Emergency Response Team.
- Processing plutonium and other actinide compounds safety and efficiently to meet the nation’s nuclear defense program needs, as well as the needs of industrial and international customers. Plutonium-processing activities consist of direct-oxide reduction, metal chlorination, americium extraction, and electrorefining. Workers also use hydrochloric and nitric acid dissolutions to perform plutonium processing and to reduce hazardous components in waste streams.

- Applying a suite of wet chemistry techniques to provide assay of plutonium, uranium, and neptunium, as well as iron determination, loss on ignition, free acid determination in plutonium solutions, special dissolutions, and preparation of standard solutions.
- Functioning as the research arm of the Waste Isolation Pilot Plant (WIPP). Los Alamos scientists have established core capabilities to study the environmental behavior of the actinide elements in a repository environment. The study of actinides is important to WIPP because the repository only accepts materials contaminated with transuranic elements (actinides).
- Using LIBS (laser-induced breakdown spectroscopy) and coulometry instruments to analyze the actinides at the Los Alamos Plutonium Facility at Technical-Area 55. A preliminary representative LIBS spectrum (average of 200 individual spectra) of a mixed actinide oxide sample indicates that the LIBS system has a resolution of 20,000 counts per second. LIBS can be used to identify, assign transitions, and analyze complex mixtures of actinide elements in the same sample. This capability supports the Laboratory's Global Security, Nuclear Deterrence, and Energy Security mission areas.
- Studying the thermodynamic and mechanical properties of a variety of nuclear materials, from single crystals of exotic plutonium compounds to aged plutonium alloys to mixed-oxide fuels. Materials properties are used over a range of temperatures in conjunction with microstructure to understand the physics and engineering performance of nuclear materials, such as in a nuclear weapon or reactor, and to provide fundamental information on the electronic structure of actinides.
- Using modern metallographic sample preparation and analysis on a variety of actinide materials to meet scientific and production missions. Core capabilities include cutting, grinding, and polishing, optical metallography and microscopy, grain-size analysis, X-ray diffraction (powder and single-crystal), and micro-hardness testing. These capabilities are used to support a myriad of programs and projects, such as Basic Actinide Science and Research, Pit Manufacturing, Pit Surveillance, Nuclear Fuels Research and Development, and the Isotopic Fuels Impact Tester.

LANL Facilities and Resources

- Los Alamos Plutonium Facility at Technical-Area 55: This facility is the nation's most modern plutonium science and manufacturing facility—it is the only fully operations, full-capability plutonium facility in the nation. The plutonium facility supports a variety of national security programs that involve stockpile stewardship, plutonium processing, nuclear materials stabilization, materials disposition, nuclear forensics, nuclear counter-terrorism, and nuclear energy.
- Chemistry and Metallurgy Research Replacement Building: Scheduled for completion in 2018, the Chemistry and Metallurgy Research Replacement Building will provide Los Alamos with a best-in-class actinide research facility and center for excellence in plutonium science. This facility will be equipped with advanced instrumentation, office space for 350 employees, a training center with classrooms, and simulated laboratory space.
- G.T. Seaborg Institute for Transactinium Science: This institute integrates research programs on the chemical, physical, nuclear, and metallurgical properties of the lighter actinide elements, with a special emphasis on plutonium. The overall

purpose of this institute is to serve as a national center for the education and training of students, visiting scientists, and faculty at all educational levels in transactinium science. The institute publishes the *Actinide Research Quarterly*, which highlights progress in actinide science.

Key Personnel at LANL

- Anthony F. Drypolcher: Actinide Process Chemistry
- Lawrence R. Drake: Actinide Analytical Chemistry

Awards

- 2012 R&D 100 Award for U-Turn: Turning Uranium Around
- 2011 R&D 100 Award for TH-ING: Thorium is Now Green

Publications

Rebecca M. Chamberlin and Lawrence R. Drake, “Capabilities and challenges in actinide analytical chemistry at Los Alamos National Laboratory,” ACS National Meeting Book of Abstracts (2011).

N. Xu, L. Tandon, D. Gallimore, E. Lujan, D.R. Porterfield, L. Colletti, and K. Kuhn, “Dissolution and assay of neptunium oxide,” Journal of Radioanalytical and Nuclear Chemistry, 1–5 (2012).

N. Xu, D. Gallimore, A. Martinez, and L. Townsend, “Determination of neptunium in plutonium materials by ICP-MS,” Journal of Radioanalytical and Nuclear Chemistry, 1–6 (2012).

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Khalil J. Spencer, Lav Tandon, Dave Gallimore, Ning Xu, Kevin Kuhn, Laurie Walker, and Lisa Townsend, “Refinement of Pu parent-daughter isotopic and concentration analysis for forensic (dating) purposes,” Journal of Radioanalytical and Nuclear Chemistry 282(2), 549–554 (2009).

Lav Tandon, Kevin Kuhn, Patrick Martinez, Joseph Banar, Laurie Walker, Terry Hahn, David Beddingfield, Donivan Porterfield, Steven Myers, and Stephen Lamont, et al., “Establishing reactor operations from uranium targets used for the production of plutonium,” Journal of Radioanalytical and Nuclear Chemistry 282(2), 573–579 (2009).

L. Tandon, E. Hastings, J. Banar, J. Barnes, D. Beddingfield, D. Decker, J. Dyke, D. Farr, J. FitzPatrick, and D. Gallimore, et al., “Nuclear, chemical, and physical characterization of nuclear materials,” Journal of Radioanalytical and Nuclear Chemistry 276(2), 467–473 (2008).